The 400-Year Wet-Dry Climate Cycle in Interior North America and Its Solar Connection

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Several high-resolution paleoclimatic records from lakes and peatlands in the northern Great Plains (NGP) show some regular patterns of late Holocene climate changes at centennial time scales. Sites from Minnesota to Alberta (Figure 1) that show centennial wet-dry cycles, especially at ~400 years, include Elk Lake, MN (400- and 84-yr; Dean 1997); Pickerel Lake, SD (~400-yr; Dean and Schwalb 2000); Moon Lake, ND (400-yr; Laird and others 1996); Coldwater Lake, ND (137-yr; Fritz and others 2000); Rice Lake, ND (400-, 201-, 129- and 99-yr; Yu and Ito 1999); Pine Lake, AB (440-yr; Campbell and others 1998); and the Upper Pinto Fen, AB (386-yr; Yu and others unpublished). The most pronounced feature in most of these NGP records is that relatively dry periods alternate with short-lived wet periods about every 400 years. Superimposed on these wet-dry cycles, stacked time series from four sites (Rice, Moon, Coldwater, and Elk lakes) for the last 1000 years show characteristic climate patterns during the Medieval Climate Anomaly (MCA) and Little Ice Age (LIA). The MCA was represented by two dry peaks centered at 650 and 850 cal BP, while the LIA was dominated by a single drought peak around 300 cal BP (Yu and others 2002). These double Medieval droughts are likely correlated with two generations of relict tree stumps as recorded in the Great Basin of California (Stine 1994, 1998).

We attribute this dominant 400-year wet-dry cycle to solar forcing (Yu and Ito 1999, 2000). Solar activities as indicated by solar proxy of cosmogenic isotopes (^{14}C, ^{10}Be) show a fundamental periodicity at ~400 years (Stuiver and Braziunas 1989; Figures 2 and 3). Dry periods in the NGP appear to correlate with solar minima (Yu and Ito 1999). Recent climate modeling suggests that solar variation likely causes a large temperature change at regional scale through a forced shift in atmospheric variability (e.g., North Atlantic Oscillation), although global-scale temperature only shows a minor response (Shindell and others 2001). These modeling results also indicate that lands and oceans show opposite responses to solar forcing. Thus we argue that the interior of the continents is more sensitive than other land areas to small changes in solar variations, especially over a longer time scale. This response in the NGP is perhaps related to a shift in dominant modes of the atmospheric pressure fields (e.g., Pacific-North American teleconnection pattern).

Aridity could be caused by either decreased precipitation (moisture availability and atmospheric circulation support) or increased evapotranspiration (net radiation and temperature). Either of these changes could occur either during particular seasons or throughout the year. Shindell and others' (2001) modeling results suggest much greater cooling in winters over the continents, in response to Maunder Minimum of solar irradiance. Similar seasonal changes might also occur in the NGP during portions of climate cycles of late Holocene. For example, during the mid-Holocene dry prairie period, ostracode data from Elk Lake, MN, indicate colder winters and summers but very dry summers (Forester and others 1987). This combination of cold and dry conditions rather than warm and dry conditions may occur more commonly than generally assumed. If this is the case during the late Holocene in the NGP, then decreased precipitation may play a greater role in causing droughts than increased evapotranspiration. Multiple proxy approach would be useful in investigating this seasonal nature of droughts in future studies, which would provide further test of modeled results. Paleoclimate records in continental interior would also contribute toward the detection of spatial pattern of climate changes, which may provide new insights into the cause and mechanism of climate changes (Bond and others 2001).

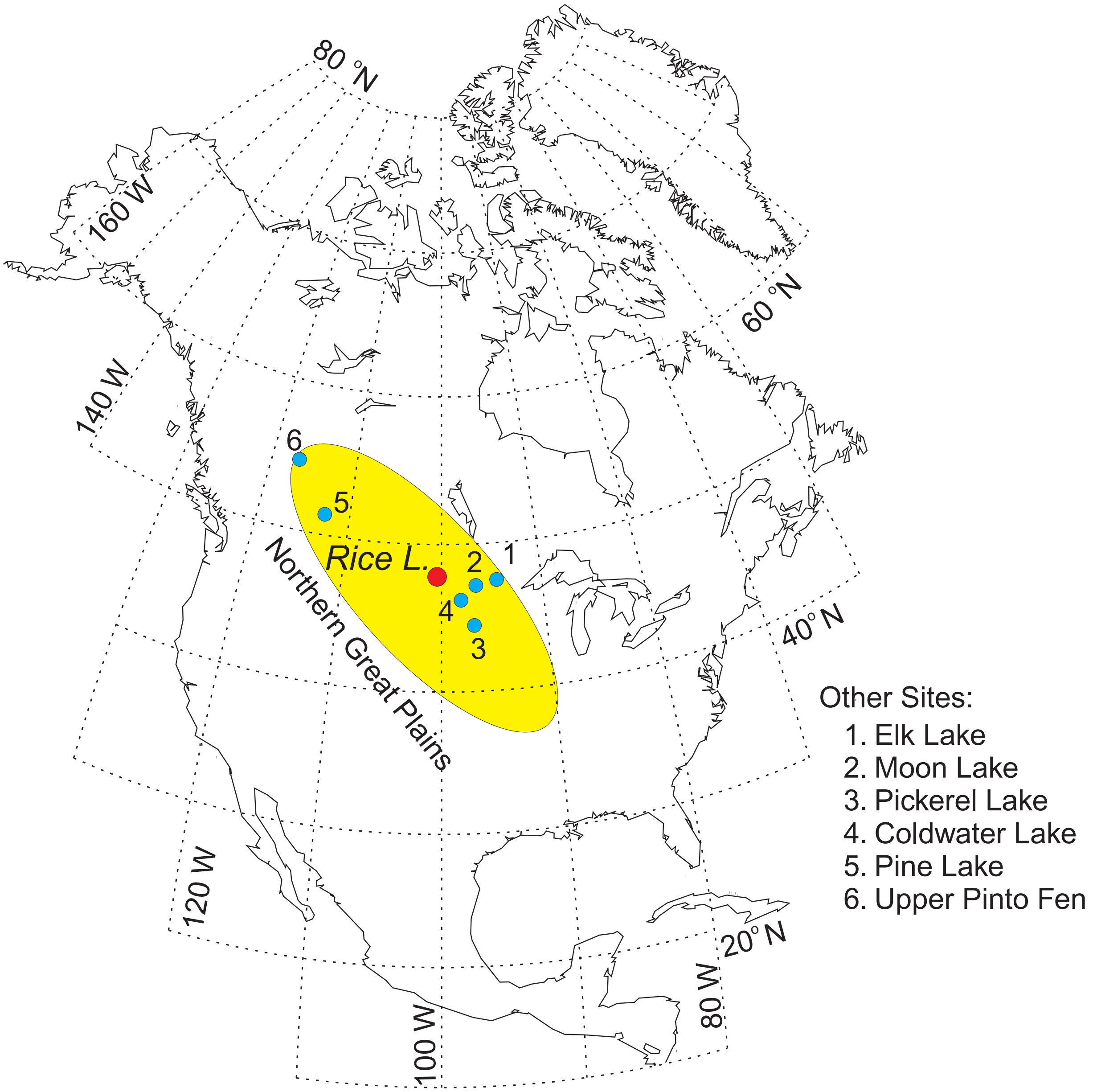

Figure 1 Map showing the location of Rice Lake, Ward County, North Dakota (Yu and Ito 1999) and other sites in the northern Great Plains of North America. (1) Elk Lake, MN (Dean 1997); (2) Moon Lake, ND (Laird and others 1996); (3) Pickerel Lake, SD (Dean and Schwalb 2000); (4) Coldwater Lake, ND (Fritz and others 2000); (5) Pine Lake, AB (Campbell and others 1998); (6) Upper Pinto Fen, AB (Z. Yu and others unpublished data).

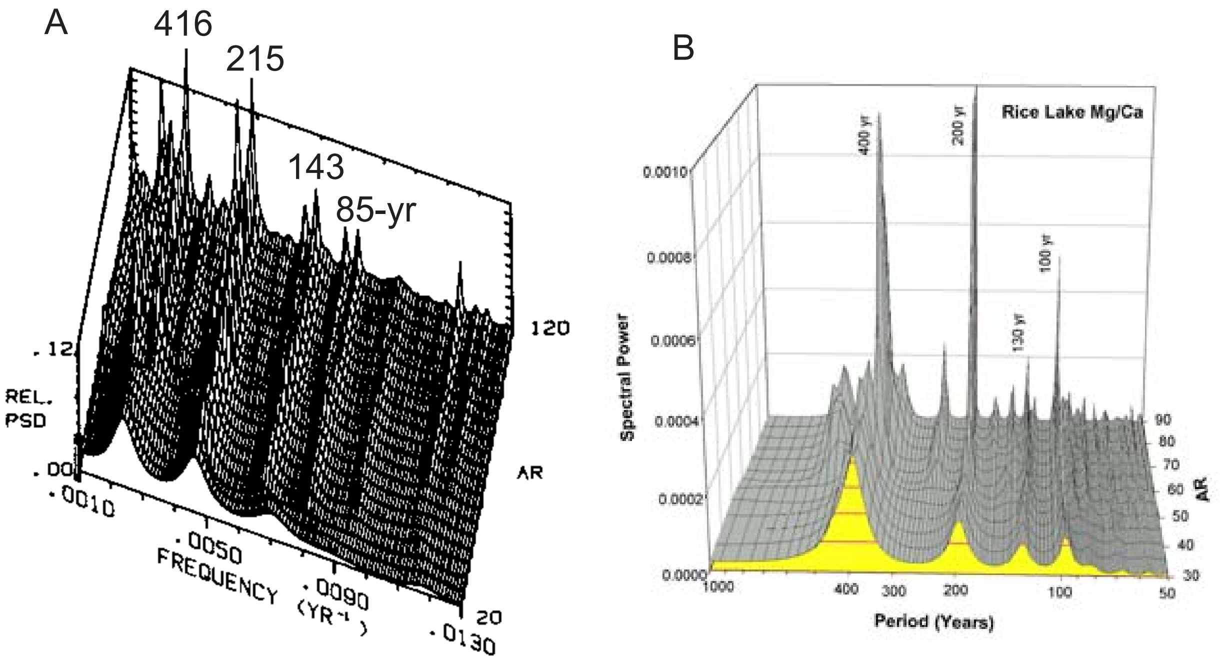

Figure 2 Similarity of spectral features of solar proxy (^{14}C time series) and climatic proxy (Mg/Ca ratios). A. Relative power spectral density (PSD) versus autoregressive (AR) order and frequency (1/yr), derived from maximum entropy method (MEM) analysis of the ^{14}C production rate. Periods (416-, 215-, 143-, and 85-yr) were converted from frequency data. From Stuiver and Braziunas (1992). B. Spectral power of Mg/Ca time series from Rice Lake. Plot shows periods (in year) and relative spectral power at different AR orders derived from MEM (Yu and Ito 1999). The dominant 400-, 200-, 130-, and 100-yr periods (as a distinct set of harmonics) persist from AR order of 30 (high confidence and low resolution) to AR order of 90 (low confidence and high resolution).

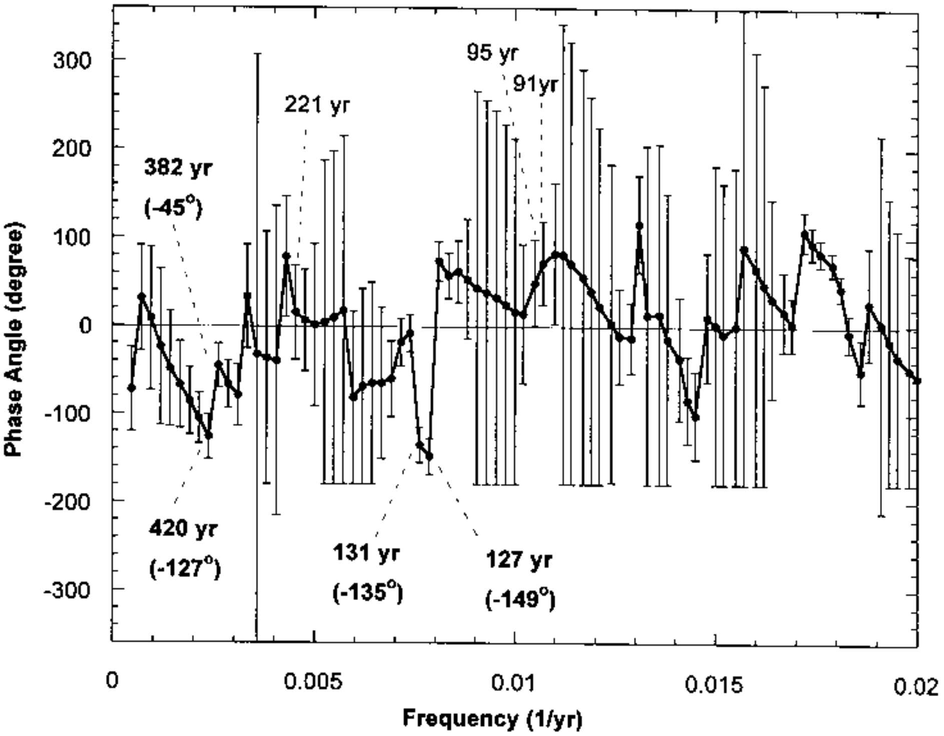

Figure 3 Phase spectrum (shown as phase angle) between Rice Lake Mg/Ca ratios and ^{14}C time series, derived from cross-spectral analysis using SPECTRUM program (Schulz and Stattegger 1997). The bold letters indicate periods (420-yr, 382-yr, 131-yr, and 127-yr) significant statistically at 80% level (coherent) with phase angle in bracket (negative values indicating the Rice series lagged behind ^{14}C series). For example, at period of 131 years Rice climatic events lag solar forcing by ~49 years (131 years * [135°/360°]). The plain letters are periods showing as peaks but below 80% significance level.

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